

Towards Teaching Analytics: Repertory Grids for Formative Assessment

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Abstract: This paper introduces the Repertory Grid Technique (RGT), developed in personal construct psychology, for Technology Enhanced Formative Assessment (TEFA). Repertory Grid is a method for eliciting personal constructs of learners about elements belonging to the topic of study. The method of Repertory Grid is presented first followed by brief descriptions of two classroom studies and two eye-tracking controlled laboratory studies. Empirical findings contribute to a better understanding of the integration of Repertory Grid into teaching as an in-class learning activity or a take-home exercise, methodological support for teachers to designing and deploying RGT exercises, and computational support for visualizing the Repertory Grid data at the individual student level and whole classroom level for “teaching analytics” purposes. We outline the design and development of the Repertory Grids for Formative Assessment (RGFA) tool and conclude with directions for future work.

Introduction

Repertory Grid Technique (hereafter RGT) is a method for eliciting personal constructs of individuals about elements belonging to a topic of study. RGT is based on the seminal contribution of psychologist George Kelly (1963, 1992), Personal Construct Theory, and subsequent theoretical and methodological developments (cf. Adams-Webber, 2006; Fransella, Bell, & Bannister, 2003). RGT has been used by both researchers and practitioners in a wide variety of fields including psychotherapy (Winter, 2003), marketing (Frost & Braine, 1967), education (Bell & Harriaugstein, 1990; Mazhindu, 1992), and information systems (Cho & Wright, 2010; Tan & Hunter, 2002). RGT consists of a family of methods and variations involving the nature of the personal construct elicitation and the rating or ranking of elements in monadic, dyadic or triadic configurations (Fransella, et al., 2003). For the purposes of formative assessment, we have decided to start researching RGT with an implementation of the widely adopted method of triadic sorting of elements for personal construct elicitation and subsequent five-point Likert-item rating of the rest of the elements (Fransella, et al., 2003). Briefly put, the triadic sorting method consists of the participants being presented sets of three elements each. For a given set of three elements (e.g. Windows, OSX, Unix), the participant is prompted to select the element (e.g., Unix) that is different from the other two (Windows, OSX) and to state how it is different as the “opposite construct” (e.g., “command line interface”). Then, the participant has to state how the two remaining elements in the triad are similar to each other as the “similarity construct” (e.g., GUI). The rest of the elements (other operating systems, in our example) are then rated on a Likert-item scale ranging from the Opposite Construct (1) to the Similarity Construct (5). The participants repeat this process until all the triads of elements are sorted into different and similar and the elements for that comparison are rated. The outcome of this exercise is the Repertory Grid (RG) consisting of rows with triads, columns consisting of elements with the first column being the Opposite Construct and the last column being the Similarity Construct, and the cell values consisting of the ratings given for elements. Based on the RG, one can qualitatively appraise learners’ “mental models”—what they see as ‘going together’, and on what dimensions—and/or apply clustering methods or dimension reduction methods to derive quantitative measures of learners’ knowledge structures. The Methodology section next details two cycles of iterative research and development of RGT in a real classroom setting and subsequent eye-tracking studies in the laboratory setting. There are three interdependent research and development objectives for the use of Repertory Grid Technique for Technology Enhanced Formative Assessment. (a) integration of Repertory Grid into the curriculum as an in-class learning activity or a take-home exercise, (b) methodological support for teachers to designing and deploying RGT exercises, and (c) computational support for visualizing the Repertory Grid data towards “teaching analytics”.

Methodology

In order to achieve these three interdependent objectives, we employed educational action research methods (Hartley, 2009) in a real classroom as described below.

Classroom Setting

Classroom setting for the in-class exercises was an undergraduate course “Internet Marketing” at the Summer University program (ISUP 2011) of the Copenhagen Business School. *Internet Marketing* was taught in two sections of about 42 students each for 150 minutes on Tuesdays and Thursdays for five consecutive weeks.

Formative Assessment using Repertory Grid Online (FARGO)

Given the pedagogical coupling between the course curriculum and facebook with regard to social media, we decided to start our research and development of RGT for Technology Enhanced Formative Assessment (TEFA) using the facebook platform. A facebook application called Formative Assessment using Repertory Grid Online (FARGO) was developed towards this purpose. FARGO was implemented by Chris Teplovs while working as a Postdoctoral Research Fellow on the NEXT-TELL project at the Computational Social Science Laboratory (CSSL) of the Copenhagen Business School.

Study #1: Repertory Grid Classroom Exercise on Consumer Decision-Making

The topic for the repertory grid exercise was Consumer Decision Making. The eight elements were: car, laptop, beer, water, airline tickets, pair of shoes, pair of jeans, movie tickets. The elements were selected to range from fast moving consumer goods to potentially luxury goods (Veblen goods) and ranging from relatively inexpensive to relatively expensive purchases involving little or great consideration time, and personal taste vs. social influences. The teacher (and the first author) made the design decision to select 10 triads to include in the exercise. The selection criteria for the triads was that each element (i.e., product) should appear at least once and in different positions in the triad (first, second and third) and with as many different elements as possible. Based on the Comparative Method (Ragin, 1987), some triads were selected from the Most Similar Systems Design (MSSD) and other from the Most Different Systems Design (MDSD) perspectives. The order of presentation of the triads was randomized to control for practice effects. The in-class exercise was administered the week before the course module on Online Consumer Psychology consisting of a lecture and a take-home exercise on Decision Heuristics Simulations. After completing the facebook RGT exercise in-class, participants were provided with a repertory grid network diagram visualizing the relationship between the elements based on the ratings provided. Participants had the option of sharing their repertory grid network diagram and the repertory grid table with their classmates and other members of the facebook page for Online Marketing. Observations of the in-class exercise activity and student feedback indicated that ten triadic comparisons and ten sets of element ratings were tedious, tiresome and boring for the students.

Study #2: Repertory Grid Classroom Exercise on Online Marketing Topics

Based on the observations from the Consumer Decision-Making exercise, FARGO 2 implemented the critical design change of reducing the number of triads to five. The second half of the course was organized into special topics on eight different kinds of online marketing. The purpose of this repertory grid exercise was (a) to inquire into students' conceptions about these eight different kinds of online marketing and adapt instructional content and delivery accordingly, and (b) to familiarize students of the existence of and the relationships between the eight different kinds of online marketing covered as special topics in the course curriculum. The in-class repertory grid exercise was administered at the midpoint of the course and the week before the special topics were scheduled. Students who didn't complete the exercise in the class were invited for an eye-tracking study in the laboratory.

Study #3: Eye-Tracking Laboratory Study of Repertory Grid Exercise of Online Marketing Topics

All students in the class were invited for an eye-tracking study in the laboratory. Study participation was voluntary and an online study registration form was used to collect students' demographic data and availability. Students who didn't complete the Online Marketing Topics in the classroom setting were assigned to complete it in the laboratory setting.

Study #4: Eye-Tracking Laboratory Study of Multiple Representations of Repertory Grid Data for Consumer Decision-Making

Students who completed *both* the Consumer Decision Making and Online Marketing Topics Repertory Grid classroom exercises were assigned to the study of multiple representations of the Repertory Grid dataset for Consumer Decision-Making.

Results

The following subsections present select findings from the two eye-tracking lab studies on repertory grid exercise task and the teaching analytics task with multiple representations of the repertory grid exercise data.

Study #3: Eye-Tracking Laboratory Study of Repertory Grid Exercise of Online Marketing Topics

Six students (3 female and 3 male) participated in the first eye-tracking laboratory study of the repertory grid exercise with the eight online marketing topics as elements. The lab study exercise was identical to the in-class exercise. The objectives of the laboratory study were (a) to investigate the time taken for construct elicitation

and the subsequent elements rating for each of the five triads, and (b) to investigate the collective gaze behaviour of participants during the construct elicitation phase and the subsequent elements rating phase for each of the five triads.

Task Time: Construct Elicitation vs. Elements Rating

Except for a couple of instances, time taken for construct elicitation was higher than the time taken to rate the elements. In the two instances where the elements rating time was greater than the construct elicitation time, students had to relate opposite and similarity constructs that were specific to the three elements in the triad to the five other elements. One student commented that he would have chosen different constructs if he could go back. Analysis of the talk aloud and the structured interview data indicates that students spent more time on construct elicitation when one or more of the elements in the triad were unfamiliar to them (like adver gaming, augmented reality advertising). No order effects were found.

Gaze Behaviour: Construct Elicitation and Elements Rating

Eye-tracking data analysis was conducted at the aggregate level for each of the five construction elicitation and elements rating tasks. An analysis of the aggregate heatmaps shows that the gaze distribution pattern is fairly similar across the five construction elicitation tasks. Students' gaze is primarily allocated to the 3 elements in the triad and the text boxes for the opposite and similarity constructs. For this area of interest (triad radio buttons and construct textboxes), the average time to the first fixation (TTFF) ranges from 0.4 seconds to 1.6 seconds. The average time spent in this area of interest out of the total task time ranges from 24% to 32%. The elements ratings heatmaps show a greater variation in the gaze distribution on the webpage. There are two areas of interest. The first area of interest is the set of pull down list controls for rating the elements and the second area of interest is the elements names. Gaze is also allocated to the scale of the elicited constructs at the top. For the pull down list controls, the first area of interest, the average time to the first fixation (TTFF) ranges from 0.2 seconds to 0.9 seconds. The average time spent in this area of interest out of the total task time ranges from 28% to 43%.

The Area of Interest (AOI) analysis was conducted on regions of the webpages that were of particular importance from a pedagogical and/or user interface design perspectives. Three areas of interest (AOI) were defined on the construct elicitation webpage corresponding to the following student actions: Selection of the different element in the triad (three radio button controls followed by the element names); Opposite construct elicitation (text box control); and Similarity construct elicitation (text box control). Results show that, on average, students' gaze allocation was higher selection of the different element in the given triad with the opposite and similarity construct text boxes receiving roughly similar gaze allocation. Three Areas of Interest (AOI) were defined for analysis of eye gaze data for the elements ratings webpages. The three AOI were: Likert scale ranging from 1 (opposite construct) to 5 (similarity construct); Names of the eight elements; and Ratings region consisting of pull down list controls ranging from 1 (opposite construct) to 5 (similarity construct). Results show that, on average, only 1% of the gaze for total exposure time was allocated to the Likert scale with the ratings region and the element names receiving 21% to 15% gaze allocation on average. User interface and user experience design implications from the AOI analysis are discussed in the next section.

Study #4: Eye-Tracking Laboratory Study of Multiple Representations of Repertory Grid Data for Consumer Decision-Making

Four female and four male students participated in the second eye-tracking laboratory study. As mentioned earlier, the study consisted of three tasks presented in a random order. Due to space limitations, we only present selected results from the repertory grid dataset uploaded to IBM's Many Eyes website: *Dynamic Word Cloud and Treemap*. Analysis of gaze data for each of the above representations is presented below:

Dynamic Word Cloud of All Constructs Elicited

The Word Cloud representation is identical to the Static version of the task in terms of the horizontal layout and the alphabetical ordering of the words. The differences were that the Word Cloud had to be composed by the students, supported dynamic interaction and content was exhaustive of the constructs from all the ten triads of the Consumer Decision Making repertory grid exercise for all the students. The task consisted of initial construction of the word cloud, free range viewing subtask followed by word finding subtask. Heatmap analysis shows that the aggregate gaze of the participants was distributed around the most salient items (larger sized words). When compared to the heatmap of the Static Word Cloud, the dynamic visualization has more regions with high aggregate gaze. Area of Interest (AOI) analysis shows that the dynamic visualization with the horizontal layout with alphabetical ordering of words results in more even gaze distribution. As it is to be expected, the most frequent word ("decision") which has the largest size receives greater gaze allocation. A side-by-side Bee Swarm analysis of the Static Word Cloud and the Dynamic Word Cloud shows that unlike the

Static case, the initial gaze allocation of the students in the Dynamic case starts at different regions rather than at the largest word. This is mostly due to the fact that the Dynamic Word Cloud had many salient words.

Dynamic Treemap of All Elicited Constructs and Elements Ratings

Treemap visualizations were designed to provide a “dashboard” view of the entire repertory grid exercise. That is Treemap visualizations can provide a comprehensive view of the both the textual data (elicited constructs) and numeric data (element ratings). As with the Line Graph and Bar Chart visualizations, students were initially instructed to freely explore and interact with the Treemap visualization with subsequent instructions for guided interaction of the functionality of the Treemap visualization. Analysis of the talk-aloud and semi-structured interview data shows that students felt that the Treemaps were the most difficult visualizations to make sense of. Heatmap analysis shows that Treemap region corresponding to the first triad followed by the regions for the second, third and eighth triads accounted for the majority of the aggregate gaze distribution at 38%. Bee Swarm analysis shows that students’ gaze paths have a preference for the left half of the Treemap visualization. Students’ gaze paths start at different points of the Treemap visualization with some coalescing in the middle phase of the task.

Discussion

Based on the results reported in the previous section, we think that the repertory grid technique with triadic sorting is highly suited for technology enhanced formative assessment. A carefully designed repertory grid exercise provides insight into students’ personal constructs on a topic. An empirical finding from the laboratory study is that time taken for construct elicitation and elements ratings could provide another dimension for pedagogical decision-making. Eye-tracking results show that while aggregate gaze distribution varies for the elements rating phase, they remain fairly uniform for the construct elicitation phase. As for the representations of the repertory grid data, eye-tracking results combined with analysis of the verbal protocols and the semi-structured interviews show that Word Clouds for constructs (text) and Line Graphs for element ratings (numbers) are effective visualizations. Interactive Treemap visualizations need to be better designed and end-users should be provided with training to comprehend and interact with the dashboard display. Implications for the different stakeholders are presented below.

Implications for Teachers

In designing repertory grid exercises, teachers should pay particular attention to the previous domain knowledge of students and to what extent the elicited constructs are grounded in the personal experience of the students compared to the domain knowledge. An ideal repertory grid exercise would involve 6-10 elements and 5-6 triads with each element appearing at least once and in different positions of the triad when a particular element features more than once across the different triads. The repertory grid exercise could be designed for individual students or as a computer supported collaborative learning (CSCL) exercise involving a small group of students. The pre-test and post-test paradigm could be applied to solicit individual or group repertory grids before and after a particular curriculum module has been taught. Further, the teacher can make his or her own repertory grid available to the students for reflection, and repertory grids of domain experts for benchmarking and guided inquiry. Post repertory grid exercise tasks could include asking the individual students or groups to reflect on their own repertory grids, to inspect the repertory grids of their peers or domain experts, and/or to inspect the visualizations of the repertory grids for the entire class. An additional implication from the classroom exercises and the eye-tracking laboratory studies is that teachers could also learn about students’ current understanding based on the time taken for construct elicitation and element rating. With regard to formative assessment, teachers can inspect the constructs or the Word Cloud representations of the individual or collective constructs and discern students’ level of domain knowledge. Similarly, teachers can scrutinize the elements ratings to discern students’ ability to distinguish between the different concepts. With necessary training, teachers can make use of Treemap or some other visualization of the entire repertory grid exercise to adapt the content and didactics for that particular curriculum module. Apart from the classroom usage scenario, another usage scenario for teachers is to employ the repertory grid exercise as lightweight appraisal method for informal learning tasks. We will research this usage scenario in future work with teachers.

Implications for Students

Repertory grid exercises on topics not familiar to students either from prior formal learning settings or from personal experience seem to be perceived as challenging and engaging. That said, a well-designed repertory grid exercise on the familiar and lived practice would allow students to externalize their implicitly held constructs. Students should then be motivated and guided to reflect on their intuitions and connect their personal constructs to domain concepts. Students should also be able to co-design repertory grid exercises with peers and teachers. Co-designing a repertory grid exercise would require students to select the topic, the elements, and the number, content and order of triads. This in itself could be pedagogically effective. Finally, students should be given the

option of sharing their repertory grids with their classmates and within their social networks. Students should be able to interact with their visualizations of their individual repertory grids and those of their peers and the classroom level repertory grid. Moreover, students should be able to upload their repertory grid exercises to their e-portfolios and integrate them with their open learner models.

Implications for Researchers

From a learning sciences research standpoint there are at least two lines of inquiry to pursue. The first line of research is to build on existing work in personal construct psychology in understanding the underlying psychological processes of the repertory grid technique (RGT). The second line of inquiry is into research and development of methodological and computational support for teachers to design and evaluate RGT exercises for formative assessment purposes. Particular attention should be paid to the time on task for construct elicitation and element ratings phases of the RGT exercise in addition to the personal constructs and the ordering of elements on the bipolar scale of the opposite and similarity constructs. Change over time in the repertory grids of students as they progress through curriculum and acquisition and development of “professional vision” (Goodwin, 1994) for teachers are two important research considerations.

Implications for Design

The findings from the classroom exercises and the eye-tracking laboratory studies were used in the requirements gathering phase for the design and implementation of the software application, Repertory Grid for Formative Assessment (RGFA, <http://cssl.cbs.dk/software/rgfa>). Release One (R1) of RGFA is designed to provide a simple interface for teachers to design a repertory grid exercise and deploy it to a group of students. RGFA is designed from the scratch to integrate with a wider technology infrastructure developed in the NEXT-TELL project (www.next-tell.eu). RGFA also incorporates proper instrumentation for research purposes and interactive visualization functionalities to be developed and deployed in upcoming releases.

RGFA is our first step towards a comprehensive research program on “teaching analytics”. *Teaching Analytics* seeks to gather, archive, process, model, analyse, and visualize data from teaching and learning activities in informal and formal learning settings to empower teachers’ dynamic diagnostic decision-making for formative assessment purposes and for individual and collaborative learning purposes.

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